



Using A Large Scale Environment To Understand Passive Microwave Precipitation Biases Over Land

Veljko Petkovic and Christian Kummerow,
Colorado State University, Fort Collins, USA e-mail: veljko@atmos.colostate.edu



Objectives

The TRMM microwave rainfall retrieval over land was based strictly on the global-mean relationship between high frequency brightness temperature depression (ice-scattering) and rainfall rate. This leads to relative biases in regimes that, although similar, exhibit differences between the observed and assumed ice-to-rain ratio. To better understand what causes this variability we investigate links between a large scale environment and microphysics and organizational structure observed over the regions of similar surface type but opposite rain rate biases.

Regional Biases of GPROF Retrieval

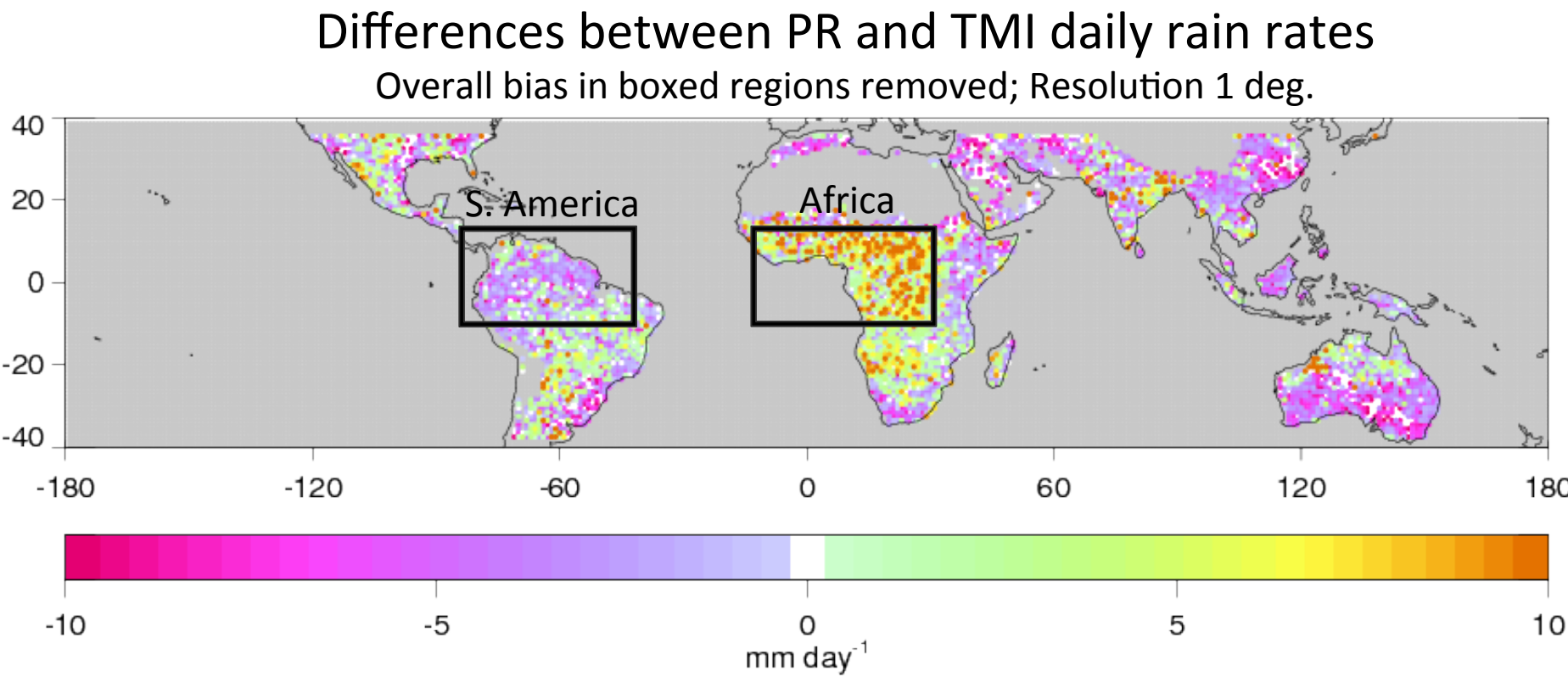


Figure reveals regions where GPROF retrieval (2010 version 2, Kummerow et al. 2015) underestimates (red-purple) and overestimates (green-orange) PR observations. The following analysis focuses on two boxed regions in South America and Africa to maximize differences in estimates by the two instruments while minimizing potential variability in surface type and climate regime (max vegetation and tropics). With the overall bias removed, the figure shows distinct opposites in the bias over Amazon and African region.

Methodology and Data

We use one year of TRMM observations to locate regions dominated by persistent disagreement in TMI and PR rainfall estimates. Then, we use ECMWF reanalysis, PR reflectivity profiles and TMI brightness temperatures to search for links between the environmental conditions and microphysical structure of precipitation regimes that can explain observed biases. Methodology from Elsaesser et al. 2010, is adopted to separate 1° x 1° precipitating scenes into convective regimes based on their top echo height and stratiform-to-convective ratio.

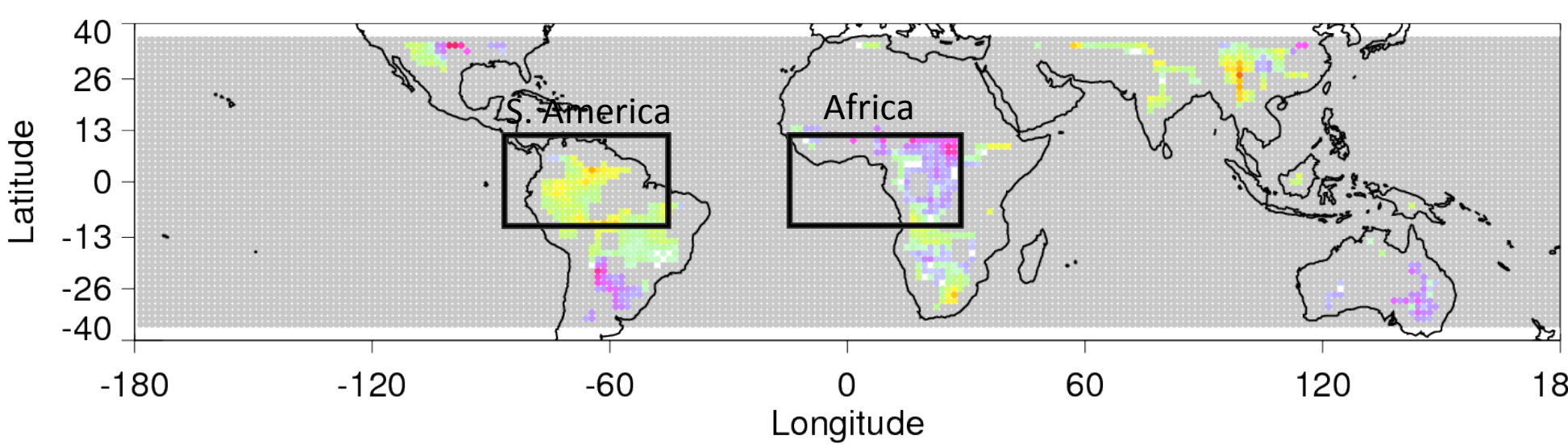
TRMM data products:

- TMI's brightness temperatures and rain rates
- PR's dBZ profiles, top echo height, precipitation type, and rain rates

ERA-Interim reanalysis (0.75° at 3- to 6-hour):

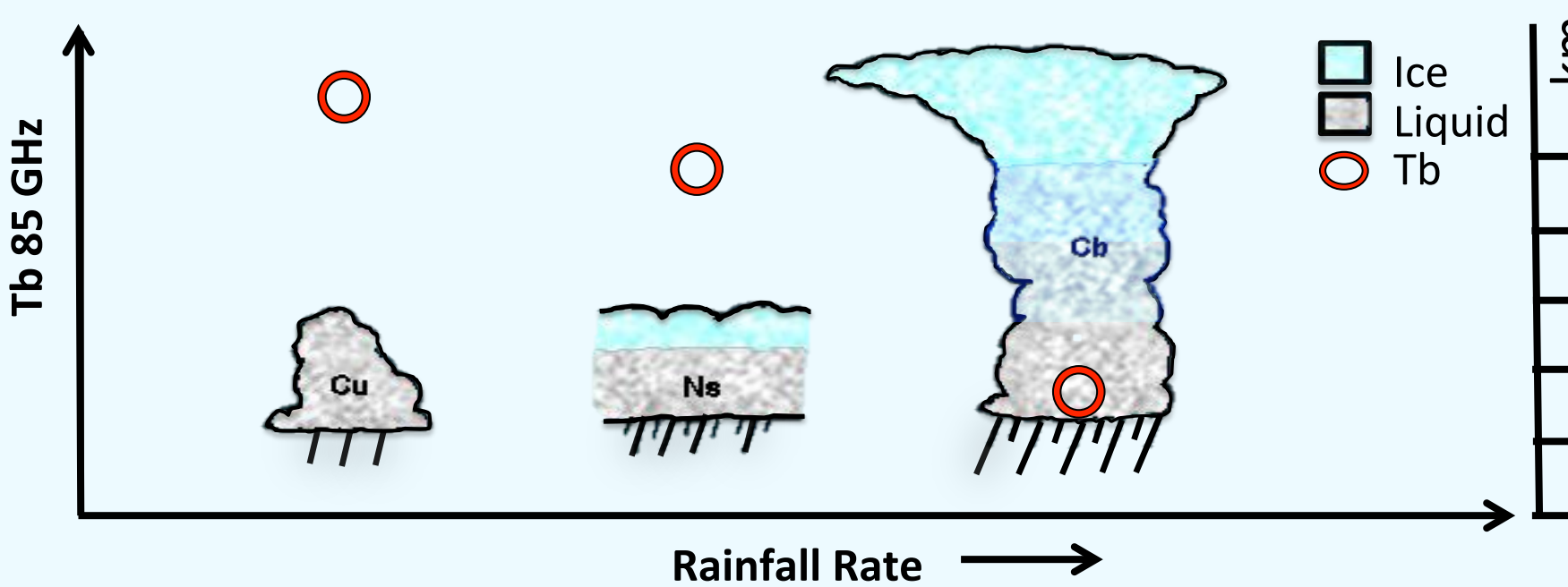
- specific humidity profile, temperature, dew point, wind profile, and CAPE

Regional Biases of Ice-to-Rain Ratio



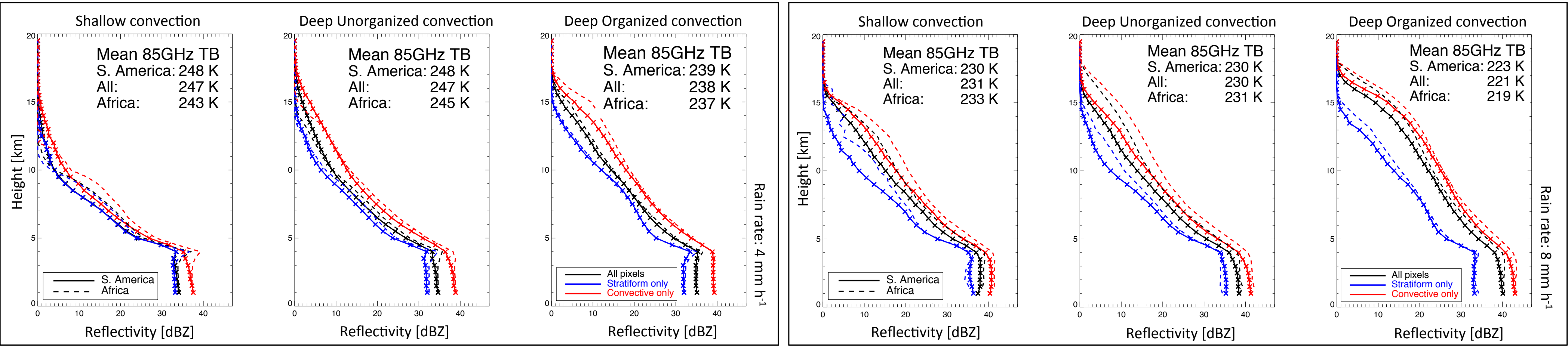
Deviation from the mean global regression between PR rainfall rate and TMI Polarization Corrected Temperature (PCT) at 85.5 GHz channel smoothed over neighboring pixels. The mean deviation over Africa and Amazon is opposite.

Ice-to-Rain Ratio and Precipitation Regime



Deep organized precipitation regimes (e.g. MCSs with strong 85 GHz Tb depressions) are expected to have higher ice-to-rain ratio than systems associated with shallow or unorganized convection (e.g. warm rain with high 85 GHz Tbs). We use this argument to test how system organization relates to regional biases of Amazon and Central Africa.

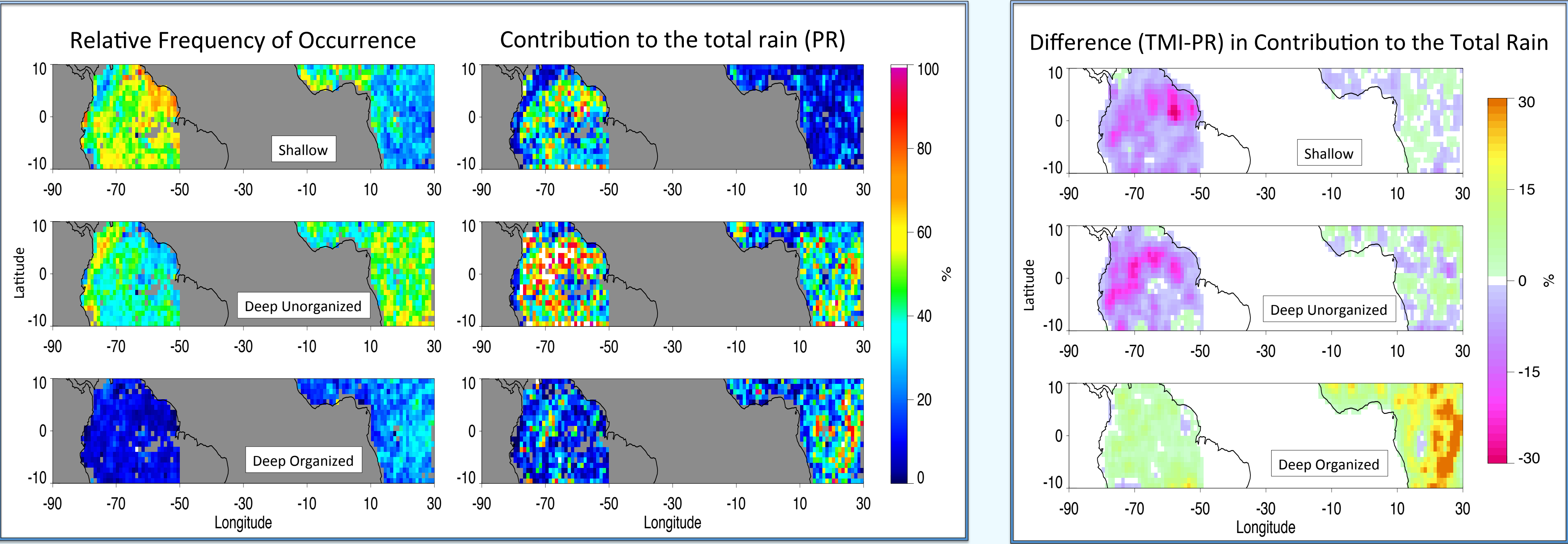
Precipitation Regimes



Using the methodology from Elsaesser et al. 2010, one degree precipitating scenes over Amazon and Central Africa region are separated into: *shallow*, *deep-unorganized*, and *deep-organized* regimes. Reflectivity profiles for low (left) and high (right) mean rain rate sampled by precipitation regime is shown.

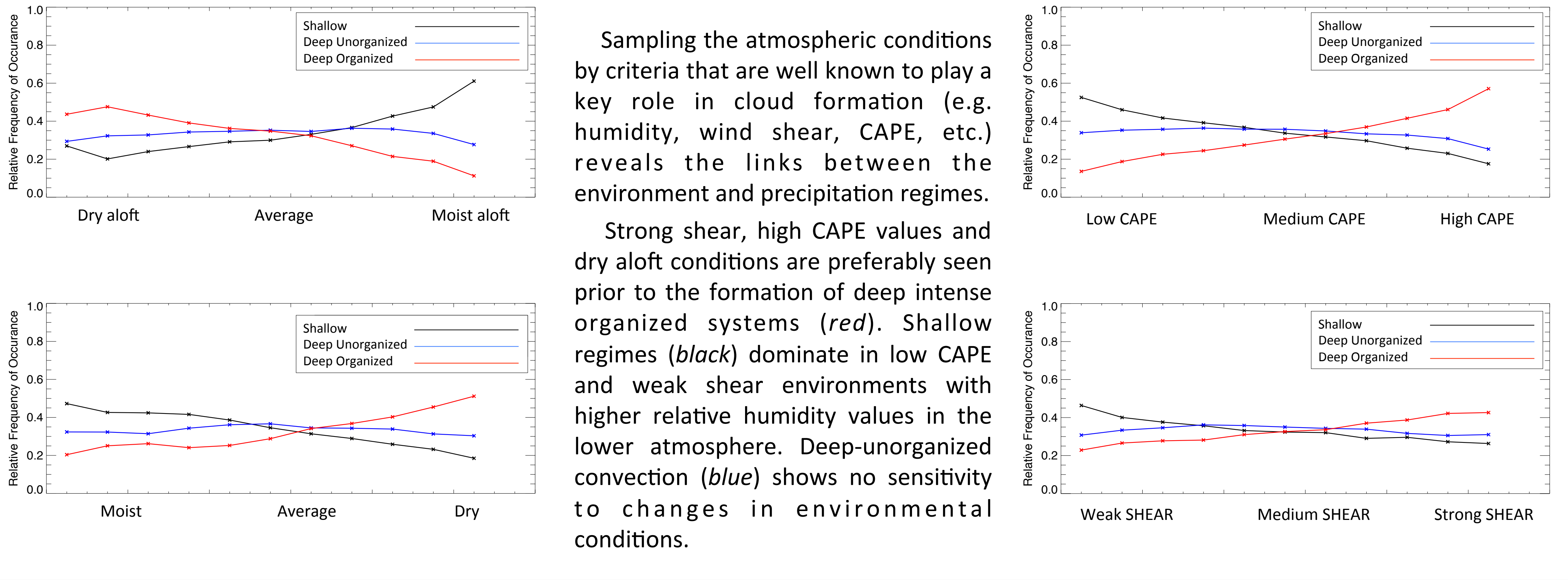
Similar vertical structure between the two regions (dashed vs. solid line), coupled with similar high frequency brightness temperatures, are seen within each of the three regimes. Conversely, when compared among each other, each of the regimes has its own characteristic profile.

GPROF Biases and Precipitation Regimes



Precipitation biases over Amazon and African regions correlate well with the extent of precipitation system organization: TMI negative biases link to the relative frequency of occurrence (RFO; *left column*) of the shallow systems (*top row*), while positive biases collocate with RFO's of deep-organized systems (*bottom row*). When accounting for contribution to total rain rate (*middle column*), precipitation regimes' RFO can explain up to 50% of the regional biases (*right column*). Thus, the ability to predict a regime's occurrence would at same be the ability to indicate expected bias.

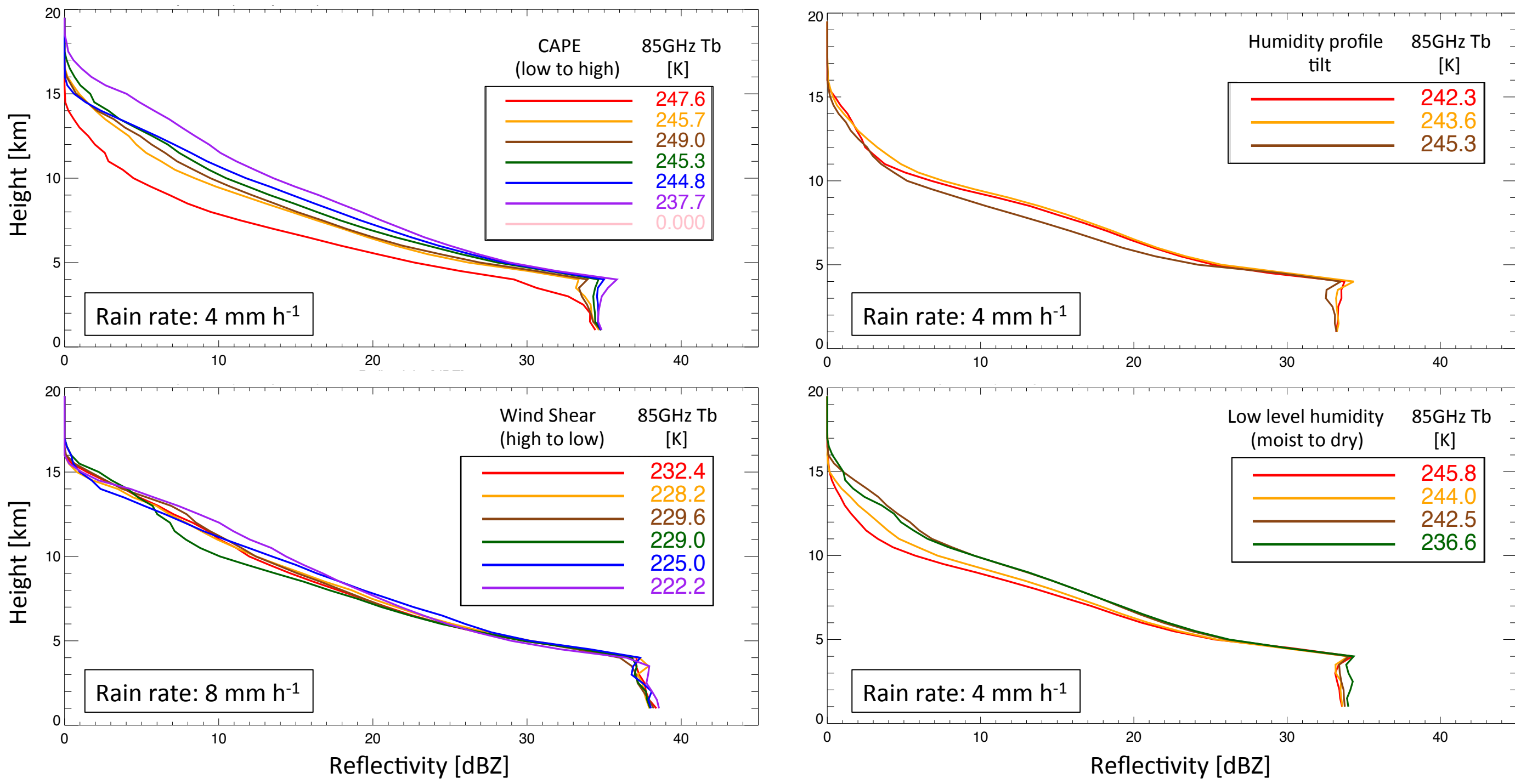
Links Between the Environment and Precipitation Regime



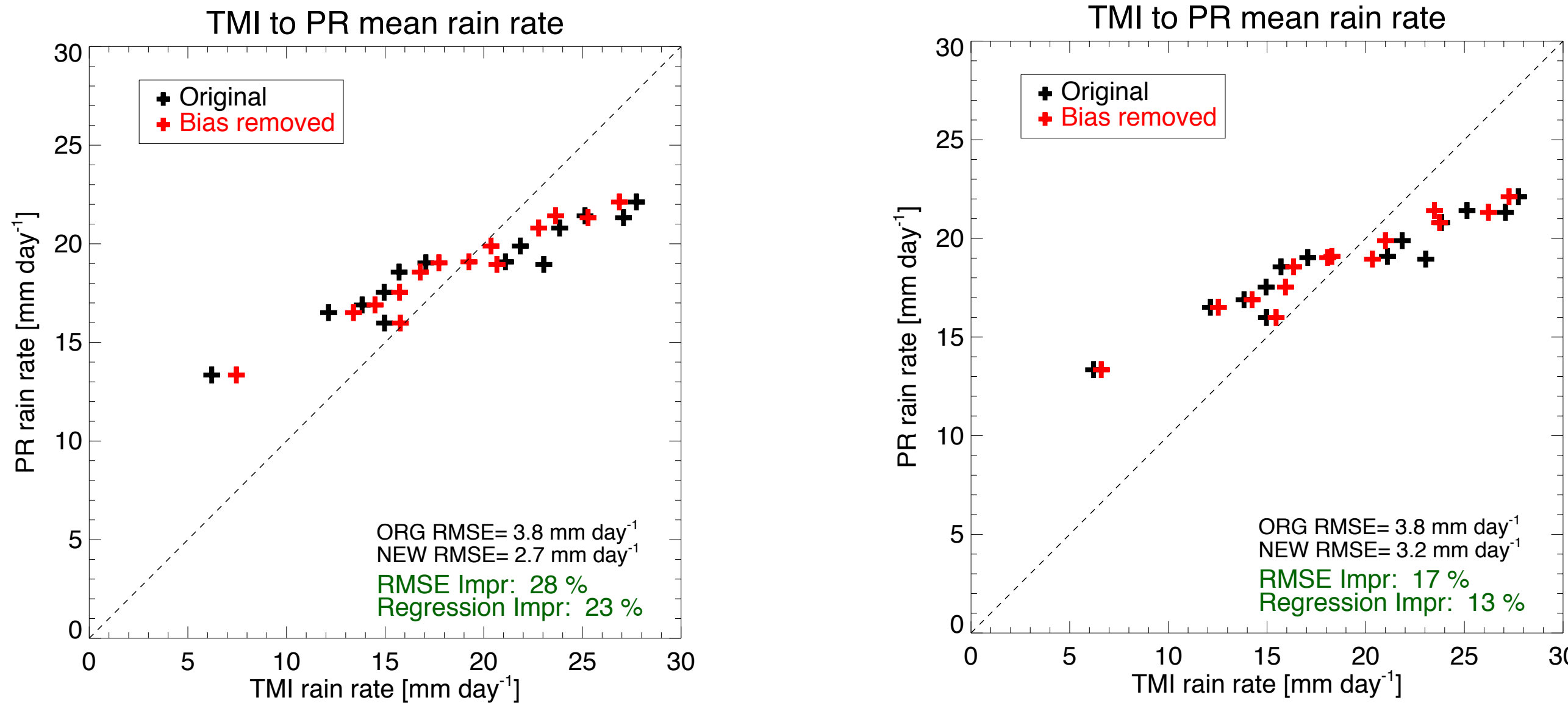
Sampling the atmospheric conditions by criteria that are well known to play a key role in cloud formation (e.g. humidity, wind shear, CAPE, etc.) reveals the links between the environment and precipitation regimes.

Strong shear, high CAPE values and dry aloft conditions are preferably seen prior to the formation of deep intense organized systems (*red*). Shallow regimes (*black*) dominate in low CAPE and weak shear environments with higher relative humidity values in the lower atmosphere. Deep-unorganized convection (*blue*) shows no sensitivity to changes in environmental conditions.

Applications



To efficiently remove the biases, the links between the environment and precipitation regimes have to be manifested in ice-scattering signal used to retrieve the rain rate. Reflectivity profiles and high frequency Tbs of 0.5° x 0.5° raining scenes sampled by the environment are shown. A shift in dBZ profile corresponds to the change in regime frequency for the given environment. At the same time, a strong change in the ice-scattering signal implies that deviation from the mean ice-scattering to rain-rate ratio can be a key cause of passive microwave precipitation biases.



A combination of CAPE and shear values (left) and humidity distribution (right) is used to predict and then remove the TMI bias in GPROF algorithm. The results show 20 to 30 % of TMI to PR RMSE reduction at 10° x 10° grid.

Conclusions

Understanding the causes of differences in the microphysics of precipitating systems in Amazon and Central Africa regions can offer a key for eliminating systematic errors seen in passive microwave satellite rainfall measurements.

- There is evidence that large-scale biases between TMI and PR observations are linked to storms' microphysical and organizational structure:
 - Distinct differences are found in vertical profiles of three structurally different precipitation regimes: shallow, deep unorganized, and deep organized convection
 - A strong consistency in bias contribution and radiometric properties is found over the Amazon and Central Africa regions for each of the three regimes
- There is evidence that precipitation regimes are linked to environmental conditions observed prior to the development of precipitating systems
 - High CAPE and strong wind shear with dry air aloft are found to be preferable conditions for development of deep-organized systems (characterized by positive GPROF bias)
 - Shallow systems (characterized by negative GPROF bias) are preceded by low CAPE and weak shear values with higher relative humidity in the lower atmosphere
 - Both the vertical structure and ice-scattering signal of precipitating scenes show strong and consistent dependence on changes in environmental conditions
- Up to 30% of satellite large scale regional biases can be removed by using the environment to predict a precipitation regime and differences between the actual and mean global ice-to-rain ratio.

References and Acknowledgments

- [1] Kummerow, C. D. et al. 2015: The Evolution of the Goddard Profiling Algorithm to a Fully Parametric Scheme (in press) *J. Atmos. Oceanic Technol.*
- [2] Elsaesser, G. S. and coauthors, 2010: Observed Self- Similarity of Precipitation Regimes Over the Tropical Oceans. *J. Climate*, 23, 2686 – 2698.

➤ Funding for this work comes from NASA *Earth and Space Science Fellowship (NESSF) Program*, and PMM grants.